We claim:

1. A method of forming a virtual substrate comprised of an optoelectronic device substrate and handle substrate comprising:

initiating bonding of the device substrate to the handle substrate, where the device substrate is composed of a material suitable for fabrication of optoelectronic devices therein and where the handle substrate is composed of an inexpensive material suitable for providing mechanical support;

improving the mechanical strength of the device and handle substrates; and

thinning the device substrate to leave a single-crystal film on the virtual substrate such as by exfoliation of a device film from the device substrate.

2. The method of claim 1 further comprising providing a pre-bonding treatment to allow the removal of a thin film.

3. The method of claim 1 further comprising cleaning and/or passivating the device and/or handle substrates to facilitate bonding.

4. The method of claim 2 further comprising cleaning and/or passivating the device and/or handle substrates to facilitate bonding.

5. The method of claim 2 where providing a pre-bonding treatment to allow the removal of a thin film comprises ion implanting the device substrate to inject an amount of gas species into the device substrate to form the internally passivated surfaces and to create an internal pressure necessary to exfoliate a layer from the device substrate upon annealing.

6. The method of claim 5 where ion implanting the device substrate comprises implanting H^+ or a combination of H^+ and He^+.

7. The method of claim 5 where ion implanting the device substrate comprises implanting an etchant chosen according to the material of the device substrate.

8. The method of claim 6 where ion implanting the device substrate comprises implanting an etchant chosen according to the material of the device substrate.

9. The method of claim 3 where cleaning and/or passivating the device and handle substrates to facilitate bonding comprises passivating the surface of both the device and handle substrates to allow hydrophobic wafer bonding.

10. The method of claim 9 where passivating the surface of both the device and handle substrates comprises enabling the formation of an intimate covalent bond between a device film, exfoliated from the device substrate, and the handle substrate in the virtual substrate to allow for the ohmic, low-resistance interface electrical properties.

11. The method of claim 3 where cleaning and/or passivating the device and handle substrates to facilitate bonding comprises eliminating adsorbed water on the surface of the device and handle substrates by means of a low temperature bake in an inert atmosphere or in vacuum.

12. The method of claim 11 where eliminating adsorbed water on the surface of the device and handle substrates by means of a low temperature bake comprising baking at a temperature such that the vapor pressure of water is below the partial pressure of water in the surrounding ambient.

13. The method of claim 9 where passivating the surface of both the device and handle substrates to allow hydrophobic wafer bonding comprises treating Group IV elemental semiconductors, including Ge, with dilute HF etches.

14. The method of claim 9 where passivating the surface of both the device and handle substrates to allow hydrophobic wafer bonding comprises treating Group

III/V and Group II/VI compound semiconductors by compound-specific chemical treatments to leave a hydrophobically passivated surface for bonding.

15. The method of claim 1 further comprising disposing a selected material X on the device substrate to enable an X-to-handle-substrate material bond with the handle substrate when an exfoliated film from the device substrate is bonded with the handle substrate, where material X includes epitaxially growing a strained thin film of Si, or a thin layer of amorphous Si deposited at low temperature.

16. The method of claim 1 further comprising disposing a selected material X on the handle substrate to enable an X-to-device-substrate material bond when an exfoliated film from the device substrate is bonded with the handle substrate, where material X includes epitaxially growing a strained thin film of Si, or a thin layer of amorphous Si deposited at low temperature.

17. The method of claim 1 further comprising disposing a selected material X on both the device and handle substrates to enable an X-to-X material bond when an exfoliated film from the device substrate is bonded with the handle substrate, where material X includes epitaxially growing a strained thin film of Si, or a thin layer of amorphous Si deposited at low temperature.

18. The method of claim 3 where cleaning and/or passivating the device and handle substrates to facilitate bonding comprises removing residual particle contamination on the bonding surfaces of the device and handle substrates.

19. The method of claim 18 where removing residual particle contamination on the bonding surfaces of the device and handle substrates comprises maintaining the device and handle substrates at a temperature greater than 50°C during the application of the CO_2 gas jets.

20. The method of claim 18 where removing residual particle contamination comprises impinging an inert gas on the substrate at an elevated temperature to remove the particles by combined physical impact and thermophoretic lifting effect.

21. The method of claim 1 where initiating bonding of the device substrate to the handle substrate comprises controlling the temperature at which the device and handle substrates are brought into contact with each other to select the strain state, whereby substrate performance in high-temperature processes is improved, or a device operation temperature strain is selected to adjust a device property such as bandgap or carrier mobility.

22. The method of claim 1 where initiating bonding of the device substrate to the handle substrate comprises holding the temperature of the device and the

temperature of handle substrates when brought into contact with each other at different magnitudes to select the strain state, whereby substrate performance in high-temperature processes is improved, or a device operation temperature strain selected to adjust a device property such as bandgap or carrier mobility.

23. The method of claim 1 where after initiating bonding of the device substrate to the handle substrate, the mechanical strength of the bond of the device and handle substrates is improved and the ion implantation layer transfer process is activated during which activation pressure is applied to the virtual substrate.

24. The method of claim 23 where the mechanical strength of the device and handle substrates is improved by using multiple pressure-temperature increments, or continuously varying pressure-temperature combinations.

25. The method of claim 24 where the mechanical strength of the bond of the device to the handle substrate is improved by applying higher pressures to ensure better substrate-substrate contact at lower temperatures prior to exfoliation where the higher pressures would at higher temperatures subdue exfoliation, and then reducing the pressure to a lower level prior to annealing at higher temperatures so that exfoliation is uninhibited.

26. The method of claim 21 where controlling the temperature at which the device and handle substrates are brought into contact with each other to select the strain state comprises maintaining the device and handle substrates at approximately equal temperatures.

27. The method of claim 21 where controlling the temperature at which the device and handle substrates are brought into contact with each other to select the strain state comprises maintaining the device and handle substrates at unequal temperatures selected to control the strain state between the device and handle substrates.

28. The method of claim 1 further comprising removing an upper portion of the device film exfoliated from the device substrate, whereby a smoother and less defect prone surface is provided for subsequent optoelectronic device fabrication.

29. The method of claim 28 where removing an upper portion of the device film exfoliated from the device substrate comprises chemically polishing the upper portion with a damage selective etch, or mechanically polishing the upper portion or both.

30. The method of claim 29 where the device and handle substrates present a Ge/Si interface and where chemically polishing the upper portion with a damage

selective etch comprises etching with a mixture of $HF:H_2O_2:H_2O$ performed at selected dilution ratios x:y:z at selected temperatures.

31. The method of claim 29 where the device and handle substrates present a Ge/Si interface and where chemically polishing the upper portion with a damage selective etch comprises etching with a mixture of $HF:HNO_3:C_2H_4O_2:H_20$ performed at selected dilution ratios x:y:z at selected temperatures.

32. The method of claim 29 where the device and handle substrates present a Ge/Si interface and where chemically polishing the upper portion with a damage selective etch comprises etching with a mixture of $H_2O_2:H_2O$ performed at selected dilution ratios y:z at selected temperatures

33. The method of claim 29 where the device and handle substrates present a InP/Si interface and where chemically polishing the upper portion with a damage selective etch comprises etching with a mixture of $HCl:H_3PO_4:H_2O_2$ used in ratios of 1:2:2 and 1:2:4.

34. The method of claim 29 where the device and handle substrates present a Ge/Si interface and where mechanically polishing the upper portion or both comprises using a colloidal silica slurry in a KOH solution.

35. The method of claim 29 where the device and handle substrates present a InP/Si interface and where mechanically polishing the upper portion or both comprises using a colloidal silica slurry in a sodium hypochlorite solution.

36. The method of claim 29 further comprising performing homoepitaxy to leave a smooth defect-free surface.

37. The method of claim 1 further comprising processing the virtual substrate as a template for growth of an optoelectronic device through hetero-epitaxy.

38. The method of claim 1 where improving the mechanical strength of the device and handle substrates comprises utilizing independently varied pressures and temperatures during bonding, wherein at low temperatures, high pressures are applied to strengthen the bond, and at high temperatures the pressure is then reduced to avoid the suppression of layer exfoliation in the device substrate.

39. The method of claim 1 where improving the mechanical strength of the device and handle substrates comprises applying a uni-axial load to the pair of substrates during annealing at a load small enough to avoid the suppression of blistering.

40. The method of claim 1 further comprising disposing a strain compensation layer on the back surface of the handle substrate.

41. The method of claim 40 where the device and handle substrate interface is GaAs/Si, InP/Si or Ge/Si and where disposing a strain compensation layer on the back surface of the handle substrate comprises disposing a film of Ge on the back surface of the Si handle substrate.

42. A virtual substrate comprised of:

an optoelectronic device substrate; and

a handle substrate bonded to the device substrate by means of a step which improves the mechanical strength of the device and handle substrates, and after which the device substrate is thinned to leave a single-crystal film on the virtual substrate such as by exfoliation of a device film from the device substrate.

43. The virtual substrate of claim 42 where the device and/or handle substrate are subjected to a pre-bonding treatment to allow the removal of a thin film prior to their bonding with each other.

44. The virtual substrate of claim 42 where the device and/or handle substrate are subjected to cleaning and/or passivating the device and handle substrates to facilitate bonding together.

45. The virtual substrate of claim 43 where the device and/or handle substrate are subjected to cleaning and/or passivating the device and handle substrates to facilitate bonding.

46. The virtual substrate of claim 43 where the device substrate subjected to a pre-bonding treatment to allow the removal of a thin film is ion implanted to inject an amount of gas species into the device substrate to form the internally passivated surfaces and to create an internal pressure necessary to exfoliate a layer from the device substrate upon annealing.

47. The virtual substrate of claim 46 where the device substrate is implanted with H^+ or a combination of H^+ and He^+.

48. The virtual substrate of claim 44 where the device and/or handle substrate subjected to cleaning and/or passivating has a passivated surface to allow hydrophobic wafer bonding to each other.

49. The virtual substrate of claim 48 where the device and/or handle substrate subjected to cleaning and/or passivating is treated to enable the formation of an intimate covalent bond between a device film, exfoliated from the device substrate, and the handle substrate when bonded together in the virtual substrate to allow for the ohmic, low-resistance interface electrical properties.

50. The virtual substrate of claim 44 where the device and/or handle substrate subjected to cleaning and/or passivating is treated to eliminate adsorbed water on the surface of the device and/or handle substrates by means of a low temperature bake in an inert atmosphere or in vacuum.

51. The virtual substrate of claim 50 where the device and/or handle substrate is treated by means of a low temperature bake comprising baking at a temperature such that the vapor pressure of water is below the partial pressure of water in the surrounding ambient.

52. The virtual substrate of claim 42 further comprising a layer of a selected material X disposed on the device substrate to enable an X-to-handle-substrate material bond with the handle substrate when an exfoliated film from the device substrate is bonded with the handle substrate.

53. The virtual substrate of claim 42 further comprising a layer of a selected material X disposed on the handle substrate to enable an X-to-device-substrate material bond when an exfoliated film from the device substrate is bonded with the handle substrate.

54. The virtual substrate of claim 42 further comprising a layer of a selected material X disposed on both the device and handle substrates to enable an X-to-X

material bond when an exfoliated film from the device substrate is bonded with the handle substrate .

55. The virtual substrate of claim 44 where the device and/or handle substrate subjected to cleaning and/or passivating is treated by removing residual particle contamination on the bonding surfaces of the device and handle substrates.

56. The virtual substrate of claim 55 where the device and/or handle substrate subjected to cleaning and/or passivating is treated by impinging an inert gas on the substrate at an elevated temperature to remove the particles by combined physical impact and thermophoretic lifting effect.

57. The virtual substrate of claim 42 where the device substrate and handle substrate are bonded together by controlling the temperature at which the device and handle substrates are brought into contact with each other to select a strain state, whereby substrate performance in high-temperature processes is improved, or a device operation temperature strain selected to adjust a device property such as bandgap or carrier mobility.

58. The virtual substrate of claim 42 where the device substrate and handle substrate are bonded together by holding the temperature of the device and the temperature of handle substrates when brought into contact with each other at different

magnitudes to select a strain state, whereby substrate performance in high-temperature processes is improved, or a device operation temperature strain selected to adjust a device property such as bandgap or carrier mobility.

59. The virtual substrate of claim 42 where the mechanical strength of the bond of the device substrate to the handle substrate is increased and an ion implantation layer transfer is activated by application of pressure to the bond.

60. The virtual substrate of claim 42 where the mechanical strength of the device and handle substrates is improved by using multiple pressure-temperature increments, or continuously varying pressure-temperature combinations.

61. The virtual substrate of claim 60 where the mechanical strength of the bond of the device to the handle substrate is improved by applying higher pressures to ensure better substrate-substrate contact at lower temperatures prior to exfoliation where the higher pressures would at higher temperatures subdue exfoliation, and then reducing the pressure to a lower level prior to annealing at higher temperatures so that exfoliation is uninhibited.

62. The virtual substrate of claim 42 where the surface of the device substrate is treated by removing an upper portion of the device film exfoliated from the device

substrate, whereby a smoother and less defect prone surface is provided for subsequent optoelectronic device fabrication.

63. The virtual substrate of claim 62 where the surface of the device substrate is treated by chemically polishing the upper portion with a damage selective etch, or mechanically polishing the upper portion or both.

64. The virtual substrate of claim 63 where the surface of the device substrate is treated by performing homoepitaxy to leave a smooth defect-free surface.

65. The virtual substrate of claim 42 further comprising an optoelectronic device fabricated in the device substrate of the virtual substrate through hetero-epitaxy.

66. The virtual substrate of claim 42 where the device substrate is composed of one selected from the group comprising Group III/V compound semiconductors (including GaAs, InP, GaN,), Group II/VI semiconductors (including CdTe,), Group IV semiconductors (including Ge for GaAs family growth), and optically usable ferroelectric oxides (including $LiNbO_4$, $BaTiO_4$).